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Effects of Salt Stress on the Fruit and Yield Quality of some Selected Tomato (*Lycopersicum esculentum* L.) Varieties.

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Abstract

The growth, production, and nutritional characteristics of crops are impacted by abiotic factors such as salinity stress. The study aimed to assess the impact of salt stress on the fruit and yield characteristics of three distinct tomato cultivars, namely Rio, Dan syria, and UTC. Salt solutions with varying concentrations of NaCl were created by dissolving NaCl in deionized water. Four treatments were established, consisting of solutions with salt concentrations of 0g/L (control, without salt), 0.5g/L, 1.0g/L, and 1.5g/L. Each treatment was reproduced three times. The NaCl solutions were administered with a frequency of 7 days. The data in the study underwent Analysis of Variance (ANOVA). Rio outperformed the other varieties in terms of fruit quantity, fresh fruit weight, and fruit pericarp thickness under high salt stress, closely followed by UTC variety. The study also found that Dan syria performed better than the other varieties in terms of fresh and dry weight of shoot, as well as fresh weight of root, under mild and extreme salinity stress. However, Rio performed better than the other varieties in terms of dry weight of root under both mild and extreme salinity stress. The salt tolerance index of the Rio, UTC, and Dan Syria varieties under extreme salinity stress are 46.79%, 20.64%, and 34.70% respectively. This indicated that the Rio variety is the most salt-tolerant of the three types, with Dan Syria variety coming close.

Keywords: Abiotic factor, Salt stress, Salt-tolerant, Varieties, Yield.

INTRODUCTION

Exposure to salinity has deleterious effects on the growth and development of plants and might potentially result in their death. Plants under salinity stress often show inhibited growth, accompanied by a prevalent symptom of bluish-green leaves (Zahra *et al*., 2020). Salinity inhibits plant growth and development through osmotic stress, cytotoxicity resulting from excessive salt and chloride ion absorption, and nutritional imbalance (Ludwiczak *et al*., 2021). Increased salt concentrations interfere with the processes of photosynthesis, respiration, starch metabolism, and nitrogen fixation, leading to physiological dysfunctions that reduce agricultural output (Zahra *et al*., 2020).

The excessive accumulation of salt inside plant tissues can negatively impact multiple elements of plant morphology, physiology, biochemistry, and agricultural productivity. High

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salinity levels reduce the water availability for plants, hindering water absorption by the roots due to unfavourable osmotic pressure (Shrivastava and Kumar, 2015).

According to Hasegawa (2013), Na^+ has a destabilizing effect on proteins and membranes, leading to impairment of fundamental physiological and cellular processes such as division and growth, primary and secondary metabolism, and mineral nutrition balance. In addition, sodium ions (Na^+) hinder the absorption of potassium ions (K^+), resulting in a deficiency of potassium (K^+).

Acosta-Motos *et al*. (2017) have shown that both Cl^- anions and Na^+ cations are accountable for the harmful consequences of soil salinity on plants. Every year, numerous factors can influence the nutritional value of fruit and the amount of tomatoes produced (Inculet *et al*., 2019). The salinity of the soil and irrigation water is particularly notable among these variables. According to Shrivastava and Kumar (2015), approximately 20% of all cultivated land and 33% of irrigated agricultural area worldwide are affected by high salinity. According to a study conducted by Li *et al*. (2021), tomatoes are a type of food that contains important biochemical elements with significant therapeutic potentials. The research found that consuming tomatoes contributes to approximately 85% of the recommended daily intake of lycopene for those in North America and 56-97% for persons in five European countries.

The objective of this study is to assess the impact of salt stress on the fruit and yield characteristics of three distinct cultivars of tomato (*Lycopersicum esculentum* L.).

MATERIALS AND METHOD

Study area

The research was conducted in the greenhouse located in the Botanical Garden within the University campus at GPS coordinates $9^{0}52'40''$N, $11^{0}0'37''$E, Federal University of Kashere, Gombe State. This university is situated in the northern Guinea Savanna ecological zone of Nigeria (Kolawole *et al*., 2021).

Collection of plant samples

The three local varieties of tomato seed (Rio, Dan Syria and UTC) were obtained from Tashan-Gwari in Gombe main market, Gombe state.

Nursery Beds and Transplanting

Nursery beds were prepared in the Botanical garden of Federal University of Kashere, and three local varieties of tomato seeds namely Rio, Dan syria and UTC were broadcasted on the soil in separate seeds tray, the trays were watered daily for three weeks, the seedlings were transplanted in to pot when they reached a height of about 6-7cm. The soil used for both the nursery and individual pots consist of the mixture of loam, sandy soil, and organic manure in the ratio of 3:2:1.

Salt Solution and Application

The various salt concentrations utilized in the experiment were obtained from Hillel's (2000) paper on the optimal electrical conductivity (EC) required for optimal tomato development. The highest EC value he reported was 2.5 dm/s. This corresponds to a salt concentration of 0.04m. Salt solutions with varying concentrations of NaCl were created by dissolving NaCl in deionized water. Four treatments were established: a control treatment with no salt (0g/L), a treatment with 0.5g/L of salt (T2), a treatment with 1.0g/L of salt (T3), and a treatment with

1.5g/L of salt (T4). Each treatment was replicated three times. The NaCl solution was administered to the soil where the plants are growing at regular intervals of 7 days, using a modified version of the method developed by Christol *et al*. (2015).

Experimental Design
The experimental study consists of three different varieties of tomatoes, each with four treatments. These treatments are reproduced three times, resulting in a total of 36 polythene pots. The pots are organized in a complete randomized block design (CRBD). Parameters were measured at the stage of plant maturity.

Data collection
Data collections of yield parameters and drought tolerance index commenced at maturity stage of the plants.
Fruits were harvested at their optimal level of ripeness and number of fruits per plant at maturity was tallied and documented (Latara and Ajala, 2020). The ripe fruits were measured using the electronic weighing scale and their fresh weight of fruit were recorded at the point of maturity (Latara and Ajala, 2020). The transverse sections of fully ripened fruits per plant were obtained by making horizontal cuts through the fruits. The pericarp thickness of each fruit was measured using a calibrated meter rule (Latara and Ajala, 2020). Upon the conclusion of the experiment, each individual plant shoot was collected and its fresh shoot weight (g) was measured (Latara and Ajala, 2020). The plant shoots were collected, subjected to oven drying at a temperature of 70^0C for duration of two days, and subsequently weighed to ascertain their dry shoot weights (g) (Latara and Ajala, 2020). Upon the conclusion of the experiment, each individual plant root was collected and its fresh root weight (g) was measured (Latara and Ajala, 2020). The plant roots were collected, subjected to oven drying at a temperature of 70^0C for a duration of two days, and subsequently weighed to ascertain their dry root weights (g) (Latara and Ajala, 2020).

Salt tolerance index: The salt tolerance index was calculated by dividing the total dry shoot weight of the plants treated with various salt concentrations by the shoot dry weight of the control, and then expressing it as a percentage. This calculation was based on a slightly modified approach described by Christos *et al*. (2015). The mature tomato shoots (total above-ground portion of the plants) were weighed and the shoot fresh weights were recorded. The dry weight was measured by drying the above-ground portions of the tomato plants in an oven at a temperature of 70^0C until the samples reached a consistent weight. The Drought Tolerance Index was computed using the following formula:
D.T.I. = W_X/Wo X 100
Where,
W_X = Dry weight of shoots of the stressed plants
Wo = Dry weight of shoots of unstressed plant

Data Analysis
The data gathered in the study was analyzed using Analysis of Variance (ANOVA) based on the method developed by Bello and Kolawole (2024). If a significant difference was found, the means were separated using Duncan's multiple range test at a significance level of $P<0.05$. The statistical analysis was performed using IBM Statistical Package version 20.0.

RESULTS

Effects of various concentrations of salt stress on Fruit quality per plant of the selected varieties of tomato (*Lycopersicum esculentum*) at maturity.

The impacts of the various concentrations of salt stress on the fruit quality that comprises of number of fruits, fresh fruit weight and fruit pericarp thickness of the three varieties of tomato is presented Figure 1, 2 and 3 respectively. The total number of fruits per plant across the three tomato varieties at maturity was significantly different at $p \leq 0.05$. Rio and UTC variety recorded the highest number of fruits at T1 (control) with UTC variety producing more fruits at T2 concentration, while at highest salinity concentration (T4), Rio variety produced more fruits than others (Fig. 1). There was significant difference in the total fresh weight of fruits per plant due to the different salinity stress concentrations. Fresh fruit weight of Rio variety was significantly higher than Syria and UTC variety respectively on control medium while at extreme (highest) salinity stress concentration, Rio variety performs better than UTC and Syria variety with fresh fruit weight of 24.24g, 13.75g and 13.15g respectively and significant differences was recorded at $p \leq 0.05$ across all the salt stress concentrations of the three varieties tested in comparison with control (Fig. 2). The effects of different salinity stress concentration on the thickness of the fruit pericarp at maturity on the three varieties was tested and presented in Figure 3, UTC variety produced thicker fruit pericarp than Rio and Dan syria variety on T1, T2 and T3 salt stress concentrations with Rio variety producing a thicker pericarp than the control plant at T2 (slight salinity stress), at highest (extreme) salt stress application, Rio variety produced the thickest fruit pericarp among the three varieties evaluated. Significant difference ($p \leq 0.05$) was recorded for fruit pericarp thickness on all the tested varieties across the different salinity concentrations in comparison with control.

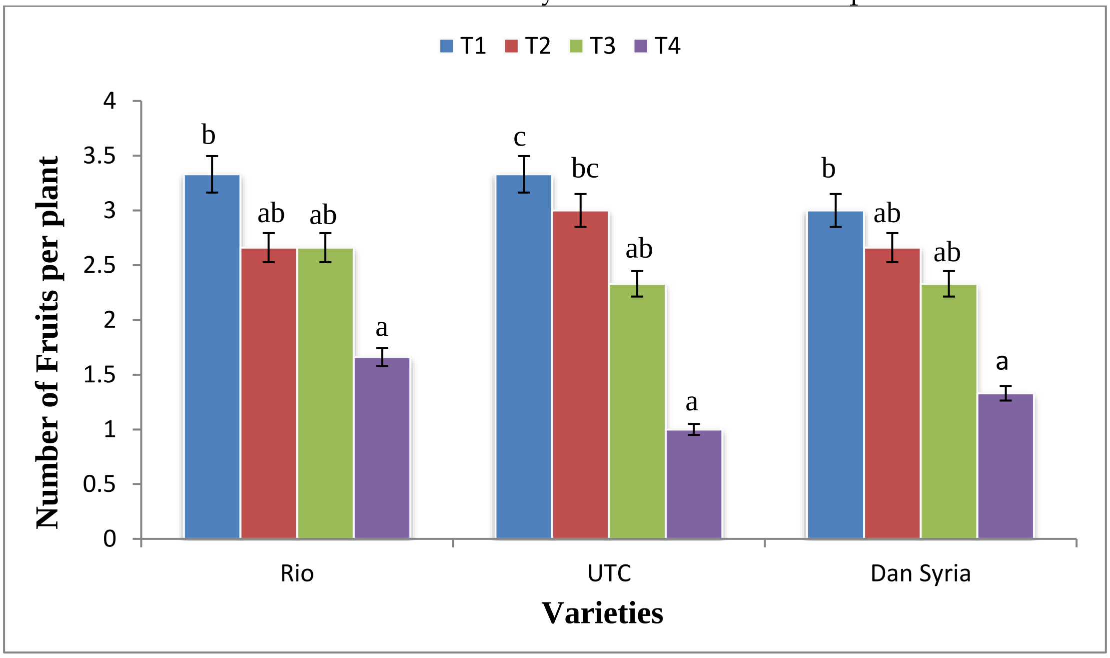

Figure 1: Effect of different salinity stress concentrations on the number of fruits of three varieties of tomato (*Lycopersicum esculentum*)

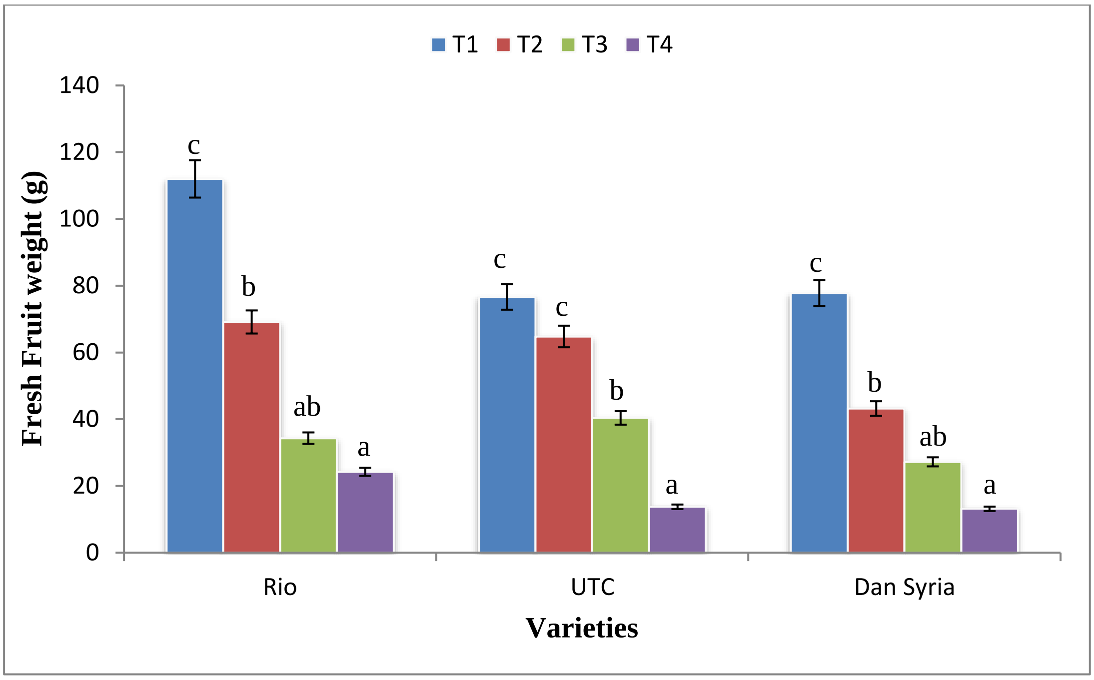

Figure 2: Effect of different salinity stress concentrations on the Fresh Fruit weight (g) of three varieties of tomato (*Lycopersicum esculentum*)

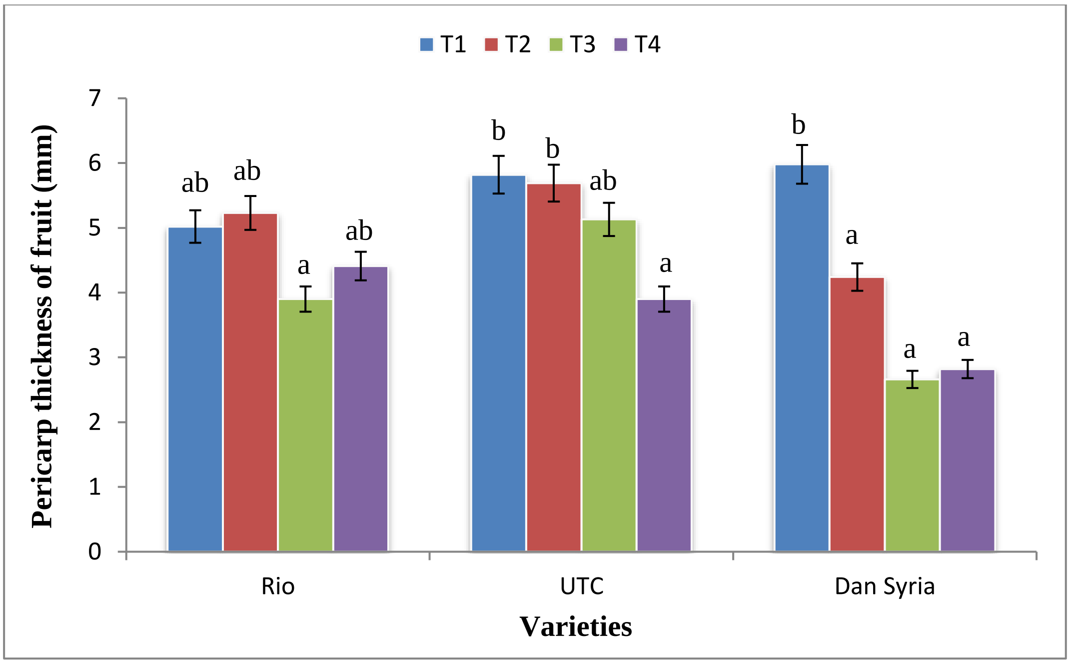

Figure 3: Effect of different salinity stress concentrations on the Pericarp thickness of fruit (mm) of three varieties of tomato (*Lycopersicum esculentum*)

Effects of various concentrations of salt stress on fresh and dry matter weight and salt tolerance index of the selected varieties of tomato (*Lycopersicum esculentum*) at maturity.

The impact of various concentration of salt stress on fresh and dry matter weight and salt tolerance index of the three varieties of tomato is presented in table 1. Fresh and dry shoot weights of the three varieties of tomato at harvest shows significant differences ($p \leq 0.05$) due to the different concentrations of salt stress, Dan syria variety produce significantly higher fresh and dry weight of shoot across all the concentrations of salt stress than UTC and Rio. Fresh and dry root weight of the three tomato varieties across different concentrations of salt stress is presented in table 1, Dan syria variety produce plant with the highest value of fresh root weight across all the concentrations of salt stress with T2 producing a slightly higher value of fresh root weight than T1 (control) followed by UTC and Rio variety respectively. For dry root weight, Dan syria variety produced plants with the highest weight of dry root on T1 and T2 salt concentration while Rio variety produced plant with the highest weight of dry root at highest (extreme) salt stress concentration (T4). Significant differences (($p \leq 0.05$) was observed on fresh and dry root weight of all the three varieties across the different concentrations of salt stress in comparison with the control. Salt tolerance index was recorded and it shows all the control recording 100% salt tolerance index as they were adequately irrigated with a pure water devoid of salinity, Rio variety recorded a better salt tolerance index across all the concentrations of salinity stress and at highest salinity stress concentration it recorded salt tolerance index of 46.79%, above Dan syria and UTC variety which recorded 34.70% and 20.64% respectively. Significant difference ($p \leq 0.05$) was recorded on salt tolerance index across the different concentrations of salt stress in comparison with control on the three tested tomato varieties at maturity.

Table 1: Effects of various concentrations of salt stress on the mean number of selected varieties of tomato (*Lycopersicum esculentum*) at maturity.

Varieties	Treatment	Fresh Shoot Weight (g)	Dry Shoot Weight (g)	Fresh Root Weight (g)	Dry Root Weight (g)	Salt Tolerance Index (%)
Rio	T1	30.46 ± 3.46^{b}	5.54 ± 1.28^{b}	5.11 ± 1.13^{b}	1.58 ± 0.31^{ab}	100.00 ± 0.00^{c}
	T2	22.21 ± 4.20^{ab}	3.33 ± 0.47^{ab}	3.38 ± 0.47^{ab}	1.49 ± 0.37^{ab}	76.48 ± 28.04^{bc}
	T3	19.10 ± 4.23^{ab}	2.98 ± 0.66^{ab}	3.07 ± 0.57^{ab}	2.05 ± 0.42^{ab}	63.30 ± 14.44^{b}
	T4	14.41 ± 2.71^{a}	1.87 ± 0.54^{a}	1.90 ± 0.52^{a}	0.83 ± 0.26^{a}	46.79 ± 11.88^{a}
UTC	T1	41.83 ± 4.85^{c}	7.08 ± 1.03^{c}	7.27 ± 1.21^{b}	2.32 ± 0.16^{c}	100.00 ± 0.00^{c}
	T2	32.86 ± 4.33^{c}	5.25 ± 0.17^{bc}	5.25 ± 0.17^{b}	1.63 ± 0.19^{b}	75.72 ± 10.99^{bc}
	T3	20.68 ± 0.56^{b}	3.37 ± 0.53^{ab}	5.61 ± 0.47^{b}	1.75 ± 0.20^{b}	60.31 ± 8.72^{b}
	T4	7.85 ± 0.86^{a}	1.53 ± 0.30^{a}	1.73 ± 0.18^{a}	0.43 ± 0.02^{a}	20.64 ± 1.77^{a}
Dan Syria	T1	40.67 ± 1.49^{b}	9.90 ± 0.39^{c}	7.15 ± 1.06^{b}	2.21 ± 0.69^{ab}	100.00 ± 0.00^{c}
	T2	39.36 ± 5.23^{b}	5.61 ± 0.54^{b}	8.53 ± 1.64^{b}	1.75 ± 0.36^{ab}	56.72 ± 5.59^{b}
	T3	29.49 ± 3.87^{a}	3.86 ± 0.72^{ab}	3.18 ± 0.44^{a}	1.38 ± 0.19^{ab}	40.89 ± 7.79^{ab}
	T4	29.55 ± 7.21^{a}	3.22 ± 0.31^{a}	3.39 ± 0.50^{a}	0.71 ± 0.16^{a}	34.70 ± 3.22^{a}

The values represent the mean value ± the standard error, based on three replications. The use of the Duncan's Multiple Range Test (DMRT) with a significance level of $p<0.05$ allows for the identification of significant differences between values in a column that have distinct superscripts.

DISCUSSION

According to Akladious and Mohamed (2018), salinity is a highly dangerous abiotic stress that has negatively affected approximately one third of all irrigated land worldwide, resulting in reduced plant output. The analysis of this result reveals the total number of fruits and total fresh weight of fruits for the three varieties: Rio, UTC, and Dan Syria. The findings consistently indicated that the control group (without salinity application) had the highest number of fruits and the highest weight of fresh fruits, this suggested that the application of salt had an adverse effect on the tomato plants in the experiment. The salinity stress concentrations have a negative impact on the number of fruits and the weight of fresh fruits. However, Rio variety performed better in terms of both number and weight of fresh fruits under extreme salinity stress. This is attributed to the higher number of flowers produced by the Rio variety compared to other varieties under mild and extreme salinity stress. These findings are consistent with a previous report by Zhang *et al*. (2016), which stated that the total yield of tomato significantly decreases as salinity levels equals and exceed 5dSm-1. Furthermore, Magan *et al*. (2008) found that the quantity and quality of tomato (*Lycopersicon esculentum* L.) harvest were dramatically reduced when saline levels increased. In this investigation, it was observed that moderate salinity does not affect the number of fruits, which is consistent with the findings of Fernandez *et al*. (2004). The decrease in the number of fruit and fresh fruit weight observed may be attributed to a reduction in the rate of enlargement during the exponential growth phase. This reduction is likely caused by the tomato plant's sensitivity to harm from accumulated ions, which occurs owing to ionic and osmotic factors during the growth season (Helaly *et al*., 2017).

The thickness of the pericarp decreases as the concentration of salinity increases. UTC variety has a thicker pericarp at low and moderate salinity concentrations, while Rio variety produced a thicker pericarp among the varieties at high salinity concentrations. Khanbabaloo *et al*. (2018) also found that salinity causes a decrease in pericarp thickness. The reduction in pericarp thickness is caused by various temporary biophysical changes, including the contraction of the plasma membrane and physical modification of the cell wall (Park *et al*., 2016).

The control treated plants had the largest biomass accumulation for both fresh and dry weight of shoot and root. Among all the varieties, the plants treated with the highest salinity concentration are the most affected. The quantity of water accessible substantially influences the production of biomass in any crop (Medrano *et al*., 2007).

Salt tolerance index indicated that all the control samples exhibited a 100% salt tolerance when irrigated with deionized water. However, Rio variety showed a higher salt tolerance index at extreme salinity concentrations. This may be due to the synthesis of stress-responsive proteins and genes, which contribute to overall stress tolerance (Kim *et al*., 2010). Consequently, Rio variety demonstrates a superior tolerance index under extreme salinity conditions.

CONCLUSION

Salinity is a non-living factor that causes a substantial detrimental effect on the growth and productivity of crops, it is clear from the result of this experiment that salinity stress constitutes a top-ranking threat to plant yield as increase in salinity leads to decrease in performance of yield in all the varieties evaluated. Rio variety performed better than the other two varieties on the number of fruits, fresh fruit weight and fruit pericarp thickness at extreme salt stress concentration closely followed by UTC variety, the experiment also revealed the result of fresh and dry matter weight of the three varieties upon exposure to different salinity stress concentrations and it shows that at mild and extreme salinity stress concentrations, Dan syria variety performed better than the two other varieties on fresh and dry weight of shoot and also on fresh weight of root at extreme salinity stress concentration while Rio variety at mild and extreme salinity concentration performed better than the other varieties on dry weight of root. Salt tolerance index showed that Rio variety at extreme salinity stress concentration performs better than the other two varieties, thus making Rio to be the variety with the highest salt tolerance of the three options evaluated.

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